A COMBINED COATING PROCESS COMPRISING MAGNETIC FIELD-ASSISTED, HIGH-POWER, PULSED CATHODE SPUTTERING AND AN UNBALANCED MAGNETRON

Field of the Invention

This invention relates to PVD coating processes incorporating magnetic field assisted, high-power, pulsed cathode sputtering together with an unbalanced magnetron.

Background to the Invention

The combination of a cathodic arc discharge and an unbalanced magnetron for the coating of tools and components which are subjected to severe wear is disclosed in US Patent 5,306,407 Hauzer et al, and in W.-D. Münz, C. Schöhnjahn, H. Paritong, I.J. Smith, Le Vide, No, 297, Vol.3/4, 2000, p. 205-223 and has proved to be very successful when employed industrially (see W.-D. Münz, I.J. Smith, SVC, 42 Ann. Tech. Conf. Proc., Chicago, IL, April 17-22, 1999, p. 350-356)

The multiply-ionised metal ions which are produced in the vapour of the cathodic arc discharge are used for low-energy ion implantation; typical acceleration voltage at the substrate: 1.2 kV, in order to produce ideal conditions for excellent layer bonding. In special cases, localised, epitaxial layer growth can even be achieved (see C. Schöhnjahn, L,A. Donohue, D.B. Lewis, W.-D. Münz, R.D. Twesten, I, Petrov, Journal of Vacuum Science and Technology, Vol.18, Iss.4. 2000, p. 1718-1723).

Bombarding the substrate surface with Cr ions has proved to be particularly successful as described in US Patent 6,033,734 Münz et al, since firstly excellent bonding strengths are achieved and secondly the macro-particles ("droplets") which are formed as an unwanted by-product have proved to be small compared with the macro-particles which are formed during cathodic arc discharge from materials with a lower melting point, e.g. Ti or TiAl (see W.-D. Münz, I.J. Smith, D.B. Lewis, S. Creasy, Vacuum, Vol. 48, Issue. 5, 1997, p, 473 - 481).

Whereas in many applications of tool coating these macro-particles, which develop into considerably enlarged growth defects during coating with an unbalanced magnetron, are only of secondary importance, they become considerably more important in anti-corrosion applications (see H.W. Wang, M.M. Stark, S.B. Lyon, P. Hovsepian, W.-D. Münz. Surf, Coat. Technol., 126, 2000, p. 279-287) or during the dry machining of hardened steels (HRC-60), for example, where layer roughness and porosity play a significant part.

With regard to the processes used in the field of industrial PVD coating, it has hitherto only been practicable to produce high metal ion densities by means of a cathodic arc discharge. On the other hand, the importance of magnetic-field assisted pulsed cathode sputtering is increasing appreciably.

By using power densities higher than 1000 $W.cm^{-2}$, it is possible to produce metal vapours in which up to 60 % of the metal atoms are ionised (see A.P. Ehiasarian, R. New, K.M.Macak, W.-D. Münz, L Hultman U. Helmersson, V. Kouznetsov, Vacuum, 65 (2202), p 147. This value is comparable with the degrees of ionisation of metal vapours achieved in a cathodic arc discharge.

Figure 1 shows an optical emission spectrum of a plasma produced in a pulsed discharge of this type, using Cr as the target, and with a power density of 3000 $W.cm^{-2}$, a peak voltage of -1200 V, a pulse duration of 50 µs and a pulse interval of 20 ms. The crucial advantage of this type of metal ion production is that no macro-particles ("droplets") are produced, and the formation of growth defects as a consequence of nucleation on macro-particles is prevented.

Summary of the Invention

According to the invention, the cathodic arc discharge constituent is replaced as an element of the ABS technique by a magnetic field-assisted, high-power, pulsed cathode sputtering source. The processes which occur on the substrate during pre-treatment remain unchanged. The negative acceleration voltages which are necessary for achieving etching effects and ion implantation remain unchanged, and typically range between -0.5 and -1.5 kV. During the treatment of tool steels or hard metals with Cr ions, the acceleration voltage (negative bias voltage) remains unchanged at -1.2 kV [4]. The subsequent coating operation using an unbalanced magnetron in non-pulsed operation also remains unchanged, since conventional power supplies offer the advantages of a more efficient energy yield and lower equipment costs.

A series of publications already exists which relate to pulsed power supplies for operating cathode sputtering sources. A typical arrangement is described in US Patent 6,296,742 of Vladimir. Kouznetsov. However, this source has been exclusively developed for the coating of substrates, and not for the pre-treatment of substrates.